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# Angular distribution of uplight at 10,000 ft over Berlin

Christopher C. M. Kyba<sup>1,2</sup>, Thomas Ruhtz<sup>1</sup>, Carsten Lindemann<sup>1</sup>,  
Jürgen Fischer<sup>1</sup>, Franz Hölker<sup>2</sup> and  
Christian B. Luginbuhl<sup>3</sup>

<sup>1</sup>Institute for Space Sciences, Freie Universität Berlin,  
Carl-Heinrich-Becker-Weg 6-10, 12165 Berlin, Germany  
email: christopher.kyba@wew.fu-berlin.de

<sup>2</sup>Leibniz Institute of Freshwater Ecology and Inland Fisheries  
Müggelseedamm 310, 12587, Berlin, German  
email: hoelker@igb-berlin.de

<sup>3</sup>US Naval Observatory Flagstaff Station  
10391 West Naval Observatory Road, Flagstaff, Arizona 86001-8521 USA  
email: cbl@nofs.navy.mil

**Abstract.** The upward emission direction of artificial light from cities is unknown, and is the most important systematic uncertainty in simulations of skyglow. We present a technique for measuring the emission for zenith angles up to 70°.

**Keywords.** instrumentation: detectors, radiative transfer

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## 1. Overview

The airmass from Earth’s surface to the top of atmosphere is greatest for horizontally propagating light, so the scattering probability is far higher for horizontally directed light. Understanding the angular distribution of artificial light emitted by cities is thus of crucial importance for simulating skyglow accurately. Because the distribution has not been measured, until now it has only been inferred from comparing skyglow observations to simulations (Luginbuhl *et al.* 2009).

By mounting two cameras on an aerial measurement platform, we performed measurements of the angular distribution of uplight at an elevation of 10,000 ft over Berlin, Germany. This system is able to measure the upwards emission from zenith to an angle of 70°, for any given azimuthal direction. Testing whether the upward emitted light is azimuthally symmetric is of interest, because it could explain the polarization of skyglow observed by Kyba *et al.* (2011). Azimuthally symmetric emission is generally assumed by skyglow models (e.g. Aubé & Kocifaj (2012), Falchi & Cinzano (2012)).

This technique is described more completely in “Two Camera System for Measurement of Urban Uplight Angular Distribution”, a forthcoming proceedings paper from the 2012 International Radiation Symposium.

## References

- Aubé, M. & Kocifaj, M. 2012, *MNRAS*, 422, 819  
Kyba, C. C. M., Ruhtz, T., Fischer, J., & Hölker, F. 2011, *J Geophys Res*, 116, D24106  
Falchi, F. & Cinzano, P. 2012, *MNRAS*, in press  
Luginbuhl, C. B., Duriscoe, D. M., Moore, A., Richard, G. W., & Lockwood, G. W. 2009, *PASP*, 121, 204